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International competitiveness of China's wind turbine manufacturing industry and implications for future development

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ABSTRACT

During 2010 and 2011, China had been the largest producer of wind turbines in the world for two consecutive years. How China can transform from being the largest producer to being the strongest producer of wind turbines is currently a great concern in the industry. The purpose of this paper is to discuss this issue from the perspective of the international competitiveness of China's wind turbine manufacturing industry. Firstly, the paper establishes a model for evaluating the international competitiveness of wind turbine manufacturing industry, which consists of five first-level indexes and 10 second-level indexes. Then, the paper uses these indexes to evaluate the international competitiveness of six leading wind turbine companies in the world—Vestas (Denmark), Gamesa (Germany), GE Wind (the USA), Nordex (Spain), Suzlon (India) and Sinovel (China). The result shows that the international competitiveness of the Chinese wind turbine company, Sinovel, ranked the fifth, lagging behind Vestas, Gamesa, GE Wind and Suzlon. Finally, the paper makes in-depth analysis on the major factors that hamper the international competitiveness of China's wind turbine manufacturing industry and provides implications for future development of the industry.

Contents

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1. Introduction

As a result of many national policies to promote renewable energy, China's total installed capacity of wind power doubled each year between 2006 and 2010 [1,2]. At the end of 2011, China's total installed wind power capacity reached 62.73 GW, ranking the first in the world for the second time after 2010 [3]. In 2010, four Chinese wind turbine companies, namely Sinovel, Goldwind, Dongfang Electric and United Power were in the top 10 largest wind turbine producers [1]. China may have become the largest wind turbine producer in the world, but does being the largest wind turbine producer equate being the strongest wind turbine producer? How do we evaluate the international competitiveness of wind turbine industry and what measures should be taken to enhance the industry's international competitiveness? These questions are currently of great concern to both practitioners and researchers in China. The purpose of this paper is to identify the factors affecting the international competitiveness of China's wind turbine manufacturing industry and recommend measures for future development of the industry.

The organization of the paper is as follows: Section 2 establishes an international competitiveness evaluation model for wind turbine manufacturing industry which consists of five first-level indexes and 10 second-level indexes. Using these indexes, Section 3 evaluates the international competitiveness of six leading wind turbine companies: Vestas (Denmark), Gamesa (Germany), GE Wind (USA), Nordex (Spain), Suzlon (India) and Sinovel (China). Section 4 makes an in-depth analysis on the factors that affect the international competitiveness of China's wind power turbine manufacturing industry. Implications for future development of the industry are discussed in Section 5. Section 6 is concluding remarks and implications for future researches.

2. International competitiveness evaluation model for wind turbine manufacturing industry

2.1. Industrial international competitiveness and its analytical framework

Competitiveness refers to the relative position of an organization against its competitors. There are different levels of competitiveness—product, firm, industry and nation. But the basic unit of analysis for understanding competitiveness is the "industry". At whatever the level of competitiveness is, in most cases, competitiveness is conceived as the comparison with other countries. A nation's industrial international competitiveness can be defined as a nation's industry "possessing competitive advantage relative to the best worldwide competitors" [4].

The study of industrial international competitiveness aims not only to evaluate industrial international competitiveness but also to identify the determinants or factors affecting it. Thus, it is important to define an analytical framework for the industrial international competitiveness. Currently, the two most commonly accepted analytical frameworks for industrial international competitiveness in China's academic literature are Michael Porter's diamond model and Jin Bei's cause-result model.

2.1.1. Michael Porter's diamond model

Michael Porter uses a diamond shaped diagram as a basis of a framework to illustrate the determinants of national advantage. The points of the diamond are described as follows: (1) *Factor conditions*: a country creates its own important factors such as skilled resources and technological base; these factors are upgraded over time to meet the demand; local disadvantages force innovations. (2) *Demand conditions*: a more demanding local market leads to national advantage. (3) *Related and supporting industries*: local competition creates innovations and cost effectiveness; this also puts pressure on local suppliers to lift their game. (4) *Company strategy, structure and rivalry*: local conditions affect company strategy; local rivalry forces company to move beyond basic advantages. Two other factors, chance events and government, can influence each determinant for better or for worse [4,5].

The diamond represents the national playing field that countries establish for their industries. Porter's model stresses that industries in a country are internationally competitive because of some national conditions. In addition, the model provides directly applicable recommendations on what to change in order to improve industrial competitiveness and that of the nation as a whole. However, Porter's model is qualitative and does not offer a quantitative measure for evaluating the effects of each determinant on competitive performance. Nonetheless, it provides a good basis for identifying the determinants affecting the competitive performance [6].

2.1.2. Jin Bei's cause-result model

The cause-result model raised by Jin Bei argues that the international competitiveness of a nation's manufacturing industry should be analyzed from both causes and results. The indexes that reflect competition advantages and potentials of a manufacturing industry are the causes of competitiveness which can be categorized into direct cause indexes and indirect cause indexes. Examples for direct cause indexes are product price, quality, brand and structure, and so on, and examples for indirect causes are technology, operation, scale of enterprises, and so on. The indexes that reflect the competition result of a manufacturing industry are termed as result indexes. Examples for result indexes are market share, total sales income, and so on [7].

2.2. International competitiveness evaluation model for wind turbine manufacturing industry

2.2.1. Evaluation objects and index construct criteria

Ideally, evaluation indexes of industrial international competitiveness should satisfy three basic criteria: first, they should cover all the companies within the industry exposed to competition, i.e. represent all companies that are subject to competition and only those companies; second, they should encompass all the markets open to competition; and, third, they should be constructed from data that are fully comparable internationally. However, none of the indexes that are available fulfill these three criteria in practice. Data and other limitations mean that compromises have to be made at every stage, so that any evaluation of international competitiveness is in fact only a rough approximation of the ideal [8].

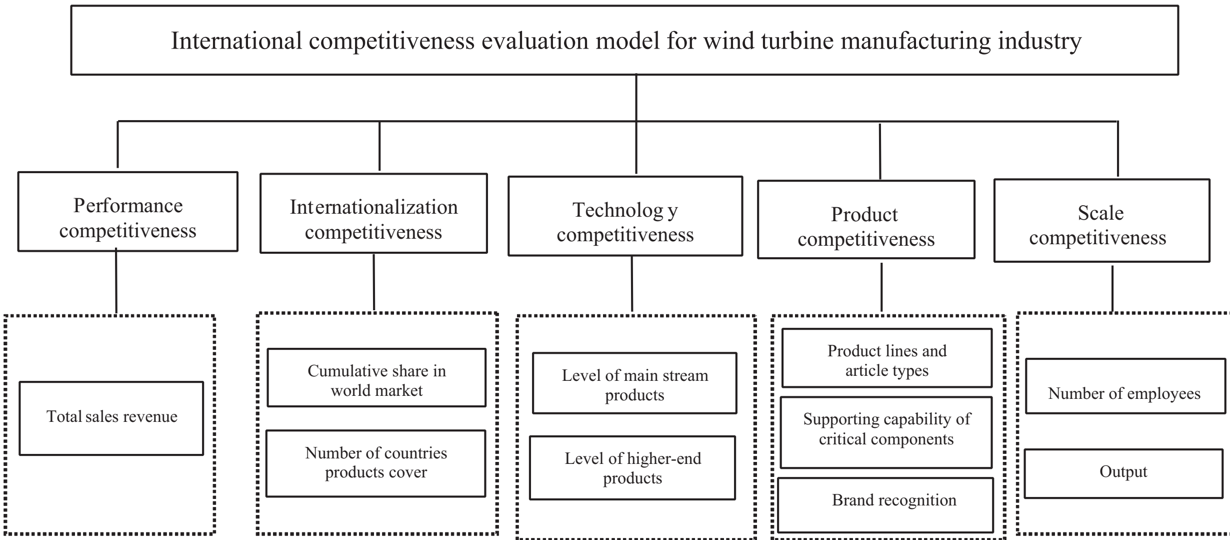


Fig. 2.1. International competitiveness evaluation model for wind turbine manufacturing industry.

Since China, the USA, Germany, Spain, India and Denmark are currently the leading countries in terms of cumulative installed capacity of wind power [1,3], in this paper we choose these six countries to be our evaluation objects. Considering the fact that it is difficult to obtain the data of the whole industry in each country and the concentration degree of wind turbine industry is very high (for example, in 2010 the share of the aggregated cumulative installed capacity of the top 5 wind turbine producers in China accounted for 67.9% of the nation's total [2]), we select one company from each country to represent the country. In other words, the index value of the selected company will represent the index value of the country it represents. The six selected companies are Vestas (Denmark), Gamesa (Spain), GE (USA), Nordex (Germany), Suzlon (India) and Sinovel (China), all are leading wind turbine producers in the world.

We define the indexes construct criteria as follows: in light of Michael Porter's diamond model and Jin Bei's cause-result model, the indexes are to be identified by taking full consideration of their completeness, conciseness, comparability, accessibility, the properties of wind turbine manufacturing industry and a combination of quantitative and qualitative approaches.

2.2.2. Evaluation model

Based on the above index construct criteria and the fact that the properties of wind power turbine manufacturing industry being technology intensive and set-nature, we establish a model for evaluating the international competitiveness of wind turbine industry as shown in Fig. 2.1. In this model, five first-level indexes including performance competitiveness, internationalization competitiveness, technology competitiveness, product competitiveness and scale competitiveness with a weight of 10%, 20%, 20%, 40%, and 10%, respectively, are determined. Under the five first-level indexes, 10 second-level indexes are determined. Amongst the 10 second-level indexes, total sales revenue, cumulative share in the world market, number of countries products cover, product lines and article types, number of employees and output are quantitative indexes while level of mainstream products, level of high-end products, supporting capability of critical components and brand recognition are qualitative indexes.

3. Evaluation of international competitiveness indexes of China's wind turbine manufacturing industry

3.1. Scores of performance competitiveness

Superior economic or market performance are generally considered an indicator of competitive advantages. Profitability is generally considered the most important measure of competitive success. Economic performance in the short term can be measured through profitability ratios. The most commonly used financial performance indicators are total sales revenue, value added per employee, return on asset (ROA), return on sales (ROS), return on investment (ROI). Costs and productivity are good signals of competitiveness especially in the case the industry is characterized by homogenous products [9].

In this paper, taking into account of the availability of data, we adopt total sales revenue in 2010, the sole second-level index, to evaluate performance competitiveness. The scores of the six companies in this respect are shown in Table 3.1.

Table 3.1
Scores of performance competitiveness.

Company	Total sales revenue in 2010[a] (billion US dollar)	Unweighted score	Weighted score (weight: 10%)
Vestas	7.954	8	0.8
Gamesa	3.664	4	0.4
GE Wind	6[b]	6	0.6
Nordex	1.336	2	0.2
Suzlon	0.983	1	0.1
Sinovel	3.002	4	0.4

Sources: Websites of the six companies [20–25].
Note: Each US$1 billion of sales revenue is calculated as 1 point.
[a] All the original data for Vestas, Gamesa, Nordex are in Euro, while the original data for Suzlon and Sinovel are in INR and Renminbi, respectively. The data in the table are the value in US dollar which are the results of the original data being converted at the average ratio of the year 2010.
[b] The total energy income of GE in 2010 financial year was about US$ 30.854 billion. The total income data for GE Wind is not available. The figure in the table is an estimated value.

Table 3.2
Scores of internationalization competitiveness.

Company	Cumulative share in world market (%)	Score	Number of countries products cover	Score	Unweighted total score	Total weighted score (weight: 20%)
Vestas	24.8	9	65	7	16	3.2
Gamesa	12.0	4	>30	4	8	1.6
GE Wind	14.3	5	Mainly the USA, Canada	1	6	1.2
Nordex	<3.5	1	34	4	5	1.0
Suzlon	6.0	2	32	4	6	1.2
Sinovel	3.5	2	Mainly China, India	1	3	0.6

Sources: Data for cumulative share in world market by the end of 2009 is from BTM Consulting Company; numbers of countries product covers by the end of 2010 are from websites of the six companies [20–25].

Note: Score of cumulative share in world market: each 3% is calculated as 1 point, the maximum is 10 point; each 10 countries a product covers is calculated as 1 point. GE Wind has no specific data. The data in the list for it is an estimated value.

3.2. Scores of internationalization competitiveness

Indexes of international competitiveness are generally trade based. Analysts of international business are concerned about that in an age of globalization. Porter, for example, identifies successful industries as ones for which there is the presence of substantial and sustained exports to a wide array of other nations and/or significant outbound foreign investment, based on skills and assets created in the home country.

There are several dimensions of internationalization. Typical uni-dimensional measures are ratio of foreign sales to total sales, share of foreign employees, number of countries in which a company owns activities. Specifically, the ratio between foreign sales and total sales is the most commonly used measure of internationalization in the studies which focus on the impact of internationalization on company performance. Other measures of internationalization could be Sullivan's degree of internationalization scale (DOI) and transnationality index (TNI) published by UNCTAD [9].

Taking into account of the availability of data, this paper evaluates internationalization competitiveness by two second-level indexes: cumulative share in the world market by the end of 2009 and number of countries the company's products cover by the end of 2010. The scores of internationalization competitiveness of the six companies are shown in Table 3.2.

3.3. Scores of technology competitiveness

Technology competitiveness refers to the ability to compete successfully in markets for new goods and services. Hence, this type of competitiveness is closely related to the innovativeness. There is, however, no available data source which measures innovativeness directly. Instead what we have are different data sources reflecting different aspects of the phenomenon. R&D expenditures, for instance, measure some (but not all) of the resources that go into developing new goods and services. Patent statistics, on the other hand, measure the output of (patentable) inventions. This is a very reliable indicator, but many innovations are not patentable. So a lot of innovation would get unaccounted for using this indicator only [10].

In this paper, technology competitiveness is evaluated by two second-level indexes: level of mainstream products and level of higher-end products. In recent years, 1.5–2.5 MW product accounts for 80% in the world wind turbine market. The level of mainstream products is thus measured by the share of the company's 1.5–2.5 MW products in the world market in 2008; the level of high-end products is measured by the level of high-end power wind turbines, particularly offshore high-end power wind turbines [11]. The scores of technology competitiveness of the six companies are shown in Table 3.3.

3.4. Scores of product competitiveness

Product competitiveness is evaluated by three second-level indexes: (1) product lines and article types; (2) supporting capability of critical components; and (3) brand recognition. The index of lines and articles of a product is measured by the variety of product lines and article types. Product lines cover four lines including kilo-level (less than 750 kW), mega-level (750–1499 kW), mega-level of the mainstream product abroad (1500–2500 kW) and multi-mega-level (2500 kW). The index of supporting capability of critical components is measured mainly by the supply capability of blade, gearbox, generator and converter. Brand recognition is measured by the international influence of the brand [11]. The scores of the six companies in product competitiveness are shown in Table 3.4.

3.5. Scores of scale competitiveness

Scale competitiveness is evaluated by two second-level indexes—number of employees and output in 2010. The scores of the six companies in scale competitiveness are shown in Table 3.5.

Table 3.3
Scores of technology competitiveness.

Company	Level of mainstream products*	Score	Level of high-end products*	Score	Unweighted total score	Weighted total score (weight:)
Vestas	16.5%	9	A	9	18	3.6
Gamesa	7.7%	4	C	5	9	1.8
GE Wind	16.9%	9	C	5	14	2.8
Nordex	1%*	1	C	5	6	1.2
Suzlon	6.9%	4	B	7	13	2.6
Sinovel	6%	3	C	5	8	1.6

Sources: Data of the five foreign companies are from Report on International Competition Status of China's Wind Power Industry in 2009: study on foreign competitors in China's Wind Power Equipment Market released by China Science and Technology Information Research Institute, June 2009 (in Chinese); data of Sinovel are estimated by the author according to the information of the company website [25].

Note: Score of the level of mainstream products: each 2% for 1 point; score of the level of high-end products is calculated on overall consideration of the share in the market of wind turbines above 2.5 MW, offshore products, and so on.

Table 3.4
Scores of product competitiveness.

Company	Product lines and article types	Score	Supporting capability of critical components	Score	Brand recognition	Score	Unweighted total score	Total weighted score (weight: 40%)
Vestas	3 Lines 8 Articles	10	A	9	AA	9	28	11.2
Gamesa	3 Lines 9 Articles	7	B	7	A	8	22	8.8
GE Wind	2 Lines	7	C	6	AA	9	22	8.8
Nordex	1 Line 6 Articles	6	B	7	B	7	20	8.0
Suzlon	3 Lines 4 Articles	8	A	7	B	7	22	8.8
Sinovel	3 Lines 3 Articles	7	C	6	B	7	20	8.0

Sources: Data are from Report on International Competition Status of China's Wind Power Industry in 2009: study on foreign competitors in China's Wind Power Equipment Market released by China Science and Technology Information Research Institute, June 2009 (in Chinese).

3.6. Overall weighted scores of the five first-level indexes

By aggregating the data in Tables 3.1 through 3.5, the overall weighted scores of the first-level indexes of the six companies are obtained (see Table 3.6).

In 2010, the newly added installed capacity of Sinovel reached 4386 MW, taking a share of 11.1% in the global market and ranking the first and second in China and in the world, respectively. But in terms of international competitiveness discussed in this paper, comparing with the other five major competitors of wind turbines in the world, Sinovel ranked the fifth, only surpassing Nordex. From the perspective of the first-level indexes, it ranked the sixth, the last position in internationalization competitiveness and product competitiveness. With respect to technology competitiveness and scale competitiveness, it ranked the fifth and fourth, respectively. Its performance competitiveness ranked the third after Vestas and GE Wind. These results indicate that comparing with the advanced wind turbine manufacturing countries in the world, the international competitiveness of wind turbine industry in China is not the strongest.

4. Analysis on the factors that hamper the international competitiveness of China's wind turbine manufacturing industry

4.1. Weakness in product quality

For a long time, China's wind turbine manufacturing industry has focused more on sales performance rather than the quality and reliability of equipments. The exceptional growth of China's wind power industry has carried potential hidden risks in quality. Due to the robust demand for local wind turbines, some local wind turbines are produced and supplied in large quantity without going through the necessary steps of prototype—trial operation—trial production in small quantity—production in batch. This unavoidably results in poor quality.

In recent years, driven by the broad development potential of local market, there are over 80 complete turbine producers and a few hundred of components producers in China. But due to reasons such as lack of capital input into testing work and public testing platform provided by the state, and the setting and monitoring of

Table 3.5
Scores of scale competitiveness.

Company	Number of employees	Score	Output (GW)	Score	Unweighted total score	Weighted total score (weight: 10%)
Vestas	23,252	10	6.3	7	17	1.7
Gamesa	7762	4	4.4	5	9	0.9
GE Wind	1700	1	6.0	7	8	1.5
Nordex	2379	2	2.4	3	5	0.8
Suzlon	13,000	7	3.5	4	11	1.5
Sinovel	2042	2	5.3	6	8	1.4

Sources: Data of the five foreign companies are from Report on International Competition Status of China's Wind Power Industry in 2009: study on foreign competitors in China's Wind Power Equipment Market released by China Science and Technology Information Research Institute, June 2009 (in Chinese); data of Sinovel are estimated by the author based on the information of the company website [25].
Note: Score of number of employees: every 2000 employees are calculated as 1 point, the utmost is 10 points; score of output: every GW is calculated as 1 point, the maximum is 10 points.

Table 3.6
Overall weighted scores of five first-level indexes.

Company	Performance competitiveness score	Internationalization competitiveness score	Technology competitiveness score	Product competitiveness score	Scale competitiveness score	Overall weighted score
Vestas	0.8	3.2	3.6	11.2	1.7	20.5
Gamesa	0.4	1.6	1.8	8.8	0.9	13.5
GE Wind	0.6	1.2	2.8	8.8	1.5	14.9
Nordex	0.2	1.0	1.2	8.0	0.8	11.2
Suzlon	0.1	1.2	2.6	8.8	1.5	14.2
Sinovel	0.4 (3)	0.6 (6)	1.6 (5)	8.0 (5)	1.4 (4)	12.0 (5)

Note: Figures in the brackets indicate the ranking position of Sinovel in the corresponding indexes of competitiveness.

standards by the government, a lot of new types of wind turbines have been hurriedly put into the market, resulting in high ratio of breakdown and ineffective use of wind turbines. Following a number of big power grid failures connected with wind turbines in the summer of 2011, the Chinese Government launched a commission to investigate the reasons for such incidents. The State Electricity Regulatory Commission (SERC) identified equipment failure as one of four major issues. Most of wind turbines manufactured by local OEMs were running without Low Voltage Ride Through (LVRT) ability. Voltage reduction caused by system failure can easily disconnect the wind turbines from the power grid.

4.2. Weakness in supporting industries

At present, China's leading wind power equipment producers are concentrated in the complete wind turbine sector. The upstream supply, however, is relatively weak. Although the production of gearboxes, blades, electric motors and hubs is now basically able to meet the market demand and the shortage of bearings has also been improved, the control systems and inverters remain in insufficient supply [12]. China still lags behind in the technology of some critical components such as main bearing, gearbox, controller, inverter and so on [13].

4.3. Weakness in overseas operation

As previously noted, the rapid development of Chinese wind turbine manufacturing industry largely depends on local demand. In other words, local demand scale has played a fundamental role in fostering the international competitiveness of China's wind turbine manufacturing industry. However, as pointed out by Michael Porter, local market scale is like a double-edged sword. On the one hand, it helps to foster industrial international competitiveness as it stimulates investment; on the other hand, huge local opportunities may prevent local companies to expand abroad, which is not beneficial for enhancing industrial international competitiveness [14].

In 2009, China started to export complete wind turbines, with a total of 20 sets with a capacity of 28.75 MW to four countries, namely India, the USA, Britain and Thailand. The main exporters were Sinovel, Sewind and Goldwind [15]. In 2010, China only exported 13 sets of complete wind turbines, with a total capacity of 15.55 MW to countries such as Cuba, the United States, Chile, Belarus and Thailand [16].

5. Implications for future development of China's wind turbine manufacturing industry

5.1. Strengthening the construction of innovation system and capability

R&D and innovation capabilities are critical success factors for wind power technology upgrading. The fostering of international competitiveness of wind turbine in Denmark and Germany is closely related to national fundamental research and building of public service system. For example, in the early 1970s, Denmark established the National Laboratory for Sustainable Energy (RISOE) which conducts many fundamental researches on renewable energy including wind power, integrates training and education as well as innovative activities with its research activities. RISOE also conducts commercial activities consisting of a wide range of innovation activities. The technology of wind power obtained by Vestas was first from RISOE [17].

China has started to establish a series of national research and development institutions. The National Energy Agency, for example, granted licenses to 16 national energy research and development (experimental) centers at the beginning of 2010, including those involved in wind power blade research and development, large scale wind power grid-connected systems research and development, and offshore wind power technology and equipment research and development. This shows that the government attaches importance to the basic research and development of the wind power equipment manufacturing industry. Generally, however, there is still a large gap between the R&D level of China's wind power industry and international standards in terms of the numbers of institutions, their employees and the quality of work [16]. It is thus recommended that the national energy research and development centers lay the foundation for improvements in innovation and the competitiveness of China's future wind power industry.

5.2. Building technical standards, national testing and certification systems for wind turbines

At the initial development stage of an emerging industry, product quality tends to be uneven. Certain technical standards must therefore be established. The reason that European wind turbines enjoy high prestige is because of its effective product testing and certification system. Denmark was the first country to promote aggressive quality certification and standardization programs in wind turbine technology and is still a world leader in this field; quality certification and standardization programs have since been used in Denmark, Germany, Japan, India and the USA [18].

In recent years, China has focused on the construction of large-scale wind farms rather than on the establishment of national technical standards. As a result, the quality of wind turbines is not well controlled. Fortunately, in 2011 the SERC has released stricter technical regulations, especially for LVRT reformation. Additionally, 18 industry standards have been released in November 2011 by the National Energy Bureau. However, these standards are far from enough. More technical standards need to be established. Meanwhile, national testing and certification systems for wind turbines should be built and mandatory testing and certification should be enforced. That is to say, new agencies need to be established, or existing agencies need more resources and staff training.

5.3. Meeting the challenge of internationalization

Due to rapid domestic market demand, China's domestic wind turbine makers kept expanding capacity. For example, Sinovel and Goldwind, the top two wind turbine makers derived more than 99% of their revenue in 2010 from China. However, in 2011 sales growth slowed after the government tightened criteria for approving new projects. With their domestic market saturated and clear signs of overcapacity and upcoming consolidation, the largest Chinese producers have announced plans for international expansion. They are looking outwards to maintain sales in markets like Europe, the U.S., Brazil, India and Australia.

The Chinese government has provided support to the expansion of domestic wind power industries operating in overseas markets through financial assistance. For example, the China Development Bank offered a US$6 billion credit facility to Goldwind in 2010 for its international expansion. Government financial support would undoubtedly provide a competitive advantage for Chinese producers in overseas markets. Another advantage of Chinese producers is their low price, which is usually 20–30% lower than that of their Western counterparts.

However, the international wind power market and wind technology present a tougher challenge for the Chinese producers to crack. The major challenge is their lack of reputation and global experience. Chinese wind turbines are still behind their Western counterparts in terms of proven safety, quality, reliability and after-sales service. There are questions about their performance level and

doubts about warranties, service and recourse if something goes wrong in the US market. Grid operators governing electrical output have progressively tightened standards in the US, while China has only had national standards since November 2011. In the European and the US markets, the wind power industry has moved beyond the frenzied initial stage when the emphasis was placed on maximum number of turbines installed. The focus is now on increasing operating efficiency, resolving performance issues rapidly, having real-time control and visibility, and reducing the maintenance time. Providing a compelling service solution is nearly as important as supplying best-in-class equipment. Thus, established wind power generating markets in Europe and in parts of the US are hard for the Chinese to penetrate [19].

How can these obstacles be overcome? Chinese producers may need to learn internationalization strategy from Suzlon. Established in 1995 with just 20 people, Suzlon is now a leading Indian wind power company which employs 13,000 people and operates across 6 continents and 32 countries, with sophisticated R&D capabilities in Denmark, Germany, India and the Netherlands. One of Suzlon's successful internationalization strategies is its innovation of an end-to-end solution package, which includes infrastructure development and goes all the way to supplying the turbines, thus offering a ready-to-use wind farm to the customer. Suzlon has also undertaken full backward integration of the supply chain by developing a comprehensive manufacturing capability for all critical components in wind turbines, thus ensuring economies of scale, quality control and assurance of supplies. This approach stands in contrast to the more piecemeal approach taken by many of its competitors [20].

6. Concluding remarks and implications for future researches

In the current context of soaring energy demand, supply constraints, environmental degradation and climate concerns, together with the influence of the breakdowns at the Fukushima-1 nuclear power plant and the radiation emission triggered by a strong earthquake in Japan in March 2011, wind power stands at the forefront in offering immediate and concrete solutions to the benefit of the world. It is expected that the world installed capacity of wind power will be expanding in the future and governments will give more priority to wind power development. On the other hand, however, competition within wind turbine manufacturing industry, especially the competition of technology is becoming intensive. The country which owns the most advanced technology will have the competitive advantage in developing and making use of wind power in the future.

China's wind turbine manufacturing industry as a whole is facing challenges from two areas: one is how to change from initial introduction, digestion and absorption of technology to self-development, upgrading of technology, and truly mastering the core technology; the other is how to build the complete industrial chain. To earn a dominant presence in the global wind energy market and foster core competitiveness, China's wind turbine producers need to develop independent R&D.

Owing to limited data sources, there are some deficiencies in this paper: (1) in the establishment of international competitiveness evaluation model for wind turbine manufacturing industry, some important evaluation indexes such as potential competitiveness index are not included as data of R&D expenditures, the ratio of R&D researchers to total number of employees, R&D capability, and so on in the six selected companies are not all available and (2) some values of the second-level indexes are estimated because of lack of relevant information and the weights are roughly decided by the author. These two deficiencies may influence the accuracy of the final results to some extent. In future researches, when there are more sufficient information, the international competitiveness evaluation model for wind turbine manufacturing industry should be improved. Weight can be decided through questionnaire survey so as to obtain more accurate results.

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